P11.6 RADAR AND DAMAGE ANALYSIS OF THE 27 MAY 2000 TORNADIC DERECHO EVENT

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1. INTRODUCTION

A growing body of evidence suggests that quasi-linear convective systems (QLCSs) produce a non-negligible number of tornadoes each year generally over the eastern United States. (Tessendorf and Trapp 2000). While the generation mechanisms of the parent circulations that produce tornadoes within supercell thunderstorms are fairly well understood, the same can not be said for those circulations observed within QLCSs. Observational studies suggest that they tend to be short lived, low level, meso-γ in scale and exhibit non descending characteristics (Trapp et al. 1999). These circulation attributes combined with our incomplete understanding of their genesis mechanism(s) makes forecasting their occurrence difficult.

The forecast process is further complicated by the fact that the spatial scale of a QLCS can be hundreds of kilometers in length. Within a QLCS, however, previous research has shown that vortices tend to form north of the apex of a bowing segment. Recent observational studies have also shown that for QLCSs propagating within non homogeneous environments containing external boundaries (not created by the QLCS itself), vortices are observed near the intersection point of the QLCS and external boundary (e.g., Przybylinski et al. 2000).

On 27 May 2000, a line of isolated cells over western Missouri propagated eastward and evolved into a tornadic QLCS over southeastern Missouri and western Illinois. The system produced areas of “straight-line wind” damage along with three circulations, two of which were tornadic as verified by a detailed ground survey of the associated damage. The objective of this study is to use radar and damage survey data to document the characteristics of the three vortices, their relationship with the QLCS and observed damage at the surface.

2. SYNOPTIC ENVIRONMENT ON 27 MAY 2000

The synoptic environment at 00 UTC on 27 May 2000 (not shown) featured a warm front extending from an area of low pressure centered over northwestern Missouri down through central and eastern Missouri, southern Illinois and western Kentucky. At 850 mb, warm air advection ahead of an advancing trough was transporting air with θ_e values greater than 340 K into southern Missouri. At 500 mb, the flow over Missouri was 40-50 knots out of the west southwest.

At 04 UTC (Fig. 1), the warm, moist southerly flow up to southern Missouri is evident with dewpoints in the upper 60s and lower 70s. The QLCS outflow boundary is also prominently seen at this time as the system moved eastward along the warm front.

3. SYSTEM EVOLUTION

A radar perspective of the QLCS evolution is shown in Fig. 2. Earlier on 27 May (0019 UTC), an area of isolated cells was observed over western Missouri. By 0217 UTC the cells had organized into a QLCS and had produced a number of areas of wind damage as noted in

27 May 2000 Surface Analysis 04 UTC

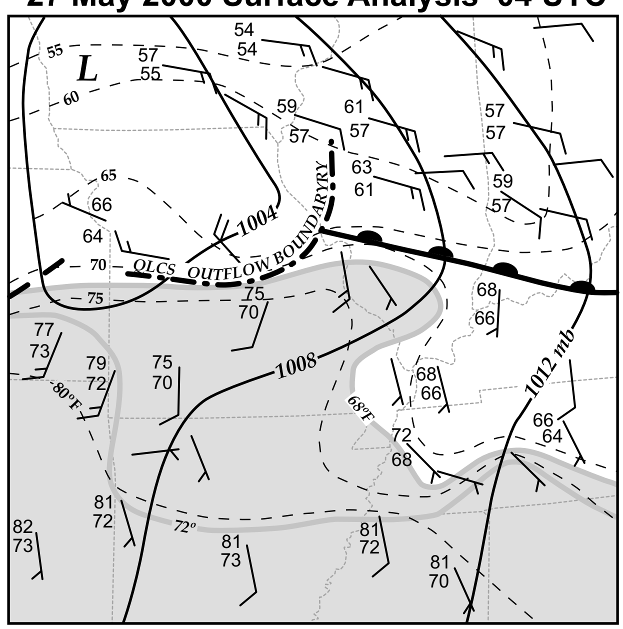

Figure 1. Surface analysis at 04 UTC on 27 May 2000. Isobars, isotherms and isodrosotherms are contoured with thick black, thin dashed and gray lines, respectively. Dewpoints greater than 72 are shaded gray. State boundaries are shown with short-dashed gray lines.

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STORM DATA. During the next two hours, the system progressed eastward into southeastern Missouri and west-central Illinois. Within the center of the line, a well-defined bowing segment reminiscent of the line echo wave pattern noted by Nolen (1959) is observed. A prominent rear inflow notch is associated with this bow echo. Two tornadoes formed at about this time are observed in the general vicinity of the bow echo. A more detailed discussion of the relationship between the tornadoes with the convective system will be presented in the next section. By 0617 UTC, the QLCS has continued to move eastward and expand in size. The number of damaging wind reports, however, have decreased over the previous two hours.

4. LOW-LEVEL CIRCULATIONS

The first of three radar-detected circulations was initially observed at 0338 UTC and is shown in Fig. 3. Notice that a couplet in the radial velocities (labeled circulation #1) can be seen just south of the merger point between the QLCS and a cell just ahead of the line. This observation is consistent with previous studies (e.g., Przybylinski et al. 2000) that have noted vortex genesis in close proximity to the merger location between isolated cells and QLCSs. How the merging process is related to vortex generation is not well understood. Circulation #1 subsequently moved to the northeast and dissipated 25 minutes later.

Also apparent in Fig. 3 is the small spatial scale of the velocity couplet. While caution must be exercised when interpreting the radial velocity data at large ranges owing to the beam width size relative to the vortex circulation diameter, the spatial scale of circulation #1 appears to be more typical of a tornado cyclone than mesocyclones observed within supercell thunderstorms (Burgess 1986). The apparent small size of this low-level QLCS circulation again speaks to the difficulty of detecting them in real time.

A time height diagram illustrating the rotational characteristics of circulation #1 is shown in Fig. 4. Circulation #1 was first detected as an intense low-level vortex with a difference between inbound and outbound storm relative radial velocities (Δv_r) of 26 ms^{-1} observed within the 0.5 degree elevation angle scan. The TVS strength rotational velocities persisted for the next five minutes at low levels. Detailed damage survey results failed to reveal any significant damage associated with this strong vortex. Thereafter, vortex intensity was relatively uniform with time.

The evolution of the other two radar-detected circulations can be seen in Figs. 4 and 5. In Fig. 5, the radar reflectivity, Doppler radial velocities and detailed damage survey results have all been superimposed beginning at 0404 UTC to reveal the relationship between the tornado-producing circulations and the bow echo embedded within the larger convective system.

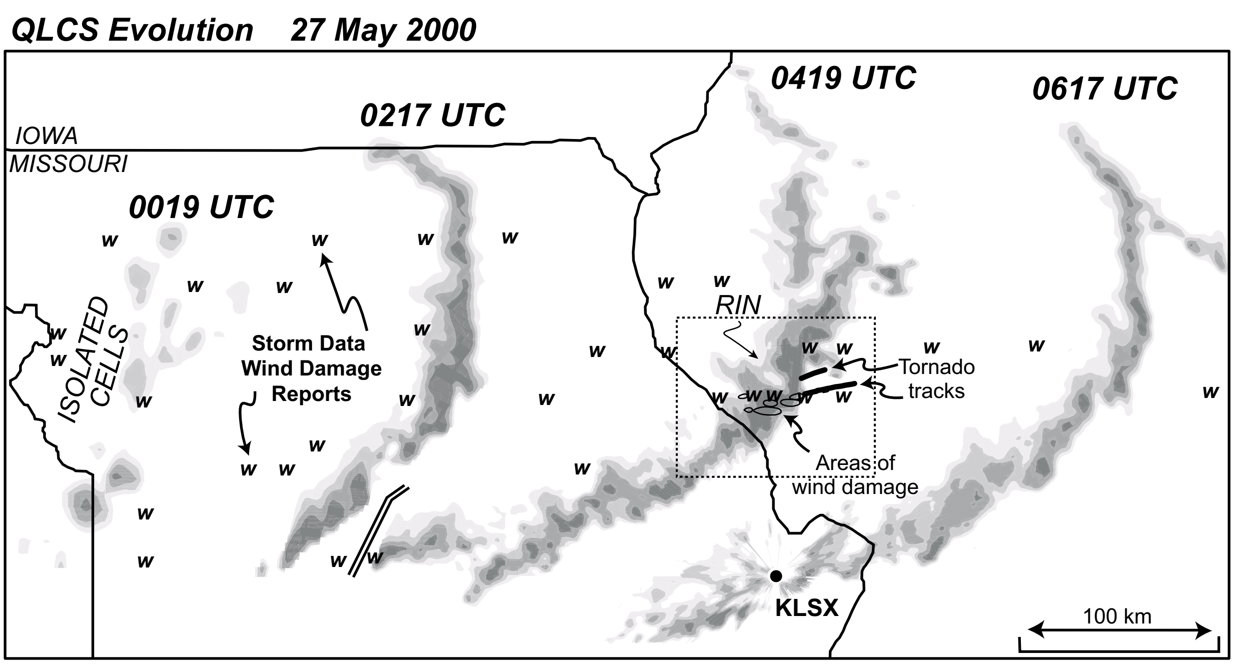

Figure 2. QLCS evolution on 27 May 2000. Radar reflectivity from KLSX at 0019, 0217, 0419 and 0617 UTC is shown. STORM DATA wind reports are plotted with a "W". Areas of wind damage (thin black lines) and tornado tracks (thick black lines) from a damage survey are also shown. Dashed box is the area shown in Fig. 5

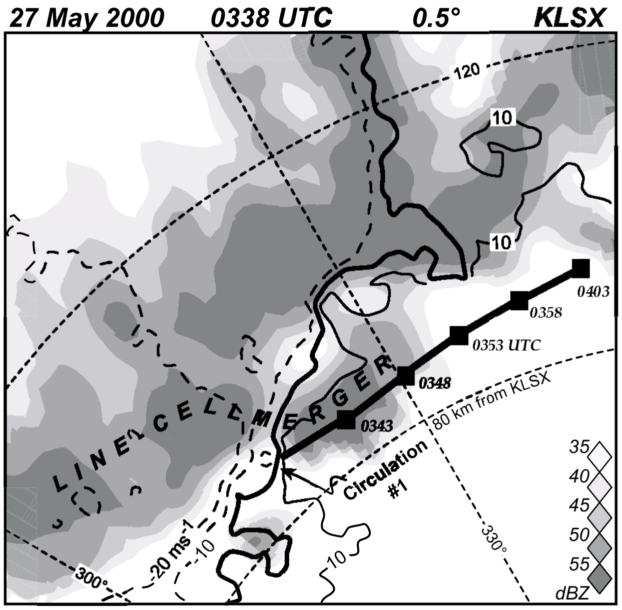

Figure 3. Radar perspective of a line-cell merger and circulation #1 is shown. Radar reflectivity (gray) and Doppler velocities (solid and dashed lines) from KLSX are shown. The thick dashed line represents the track of circulation #1. Thin dashed lines are azimuth and range rings from the KLSX WSR-88D radar.

At 0404 UTC, a bowing segment can be seen in the radar reflectivity between 330-360 degrees and 80-120 km in range. The velocity signature associated with circulation #2 can also be seen and appears to be located at or just north of the developing bow echo apex. Again, the scale of the velocity couplet is quite small, similar to circulation #1. Another interesting observation is the close correlation between circulation #2 and the location of straight-line wind damage just to the south of the circulation as determined from the damage survey. While the timing of the straight-line wind damage is not known, it is possible that circulation #2 aided in the production of some of the nearby straight-line wind damage and then became tornadic. Indeed, the time-height profile (Fig. 4b) of Δv_r shows values between 34-50 ms^{-1} illustrating an intense low-level vortex from 0359-0410 UTC, *prior to* the time it became tornadic. The data in Fig. 4b also suggest that the low-level circulation grew in depth with time.

By 0414 UTC, rotational couplets associated with both circulations #2 and #3 are evident. Circulation #2 continues to be located at or north of the bow echo apex and is again well-correlated with areas of straight-line wind damage. At about this time, however, the circulation started producing tornadic damage on the ground. The velocity couplet associated with circulation #3 is also evident further to the north of #2. Similar to circulation

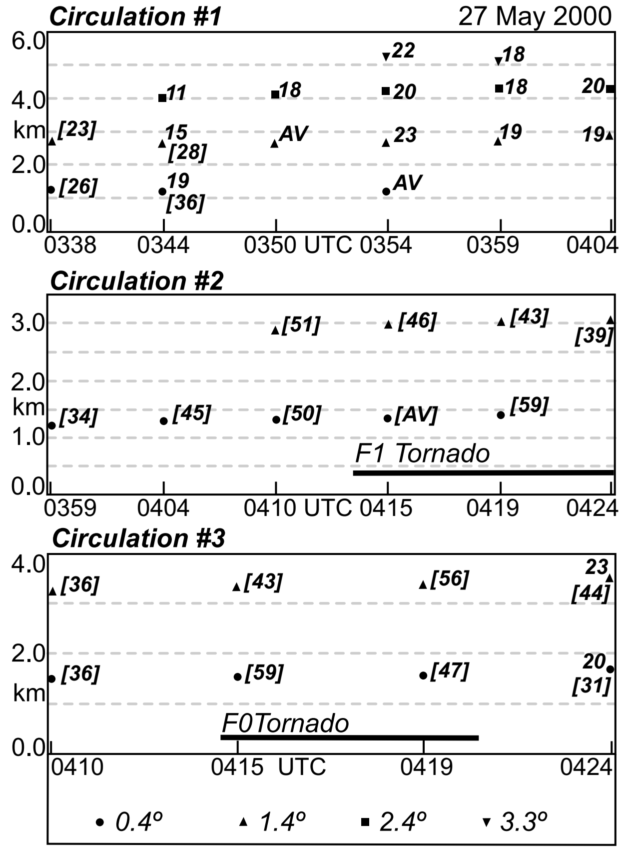

Figure 4. Time-height cross sections for circulations 1-3. Shown are storm relative maximum radial velocities along with values of the difference in inbound and outbound radial velocities in brackets. Approximate times of the two tornadoes are shown is thick black lines.

#1, it is an intense low-level vortex (Fig. 4c) that is situated just south of another line-cell merger point (Fig. 5b). At 0425 UTC, the bow echo has further strengthened and is associated with an obvious rear inflow notch. The velocity couplet associated with circulation #2 is well-correlated with the tornadic damage. Interestingly, circulation #3 has appeared to grow in size and is no longer producing tornado damage at the surface. Ten minutes later (Fig. 5d), both circulations have continued to move rapidly eastward and have further expanded in size.

5. CONCLUSIONS AND FUTURE WORK

Observations of three intense, low-level vortices observed within the 27 May 2000 QLCS over Missouri and Illinois have been presented. All three vortices were intense, low level and exhibited non descending characteristics. The first circulation formed just south of the merger point between the convective system and a cell formed ahead of it. This circulation persisted for about 25 minutes and was not tornadic. The second circulation

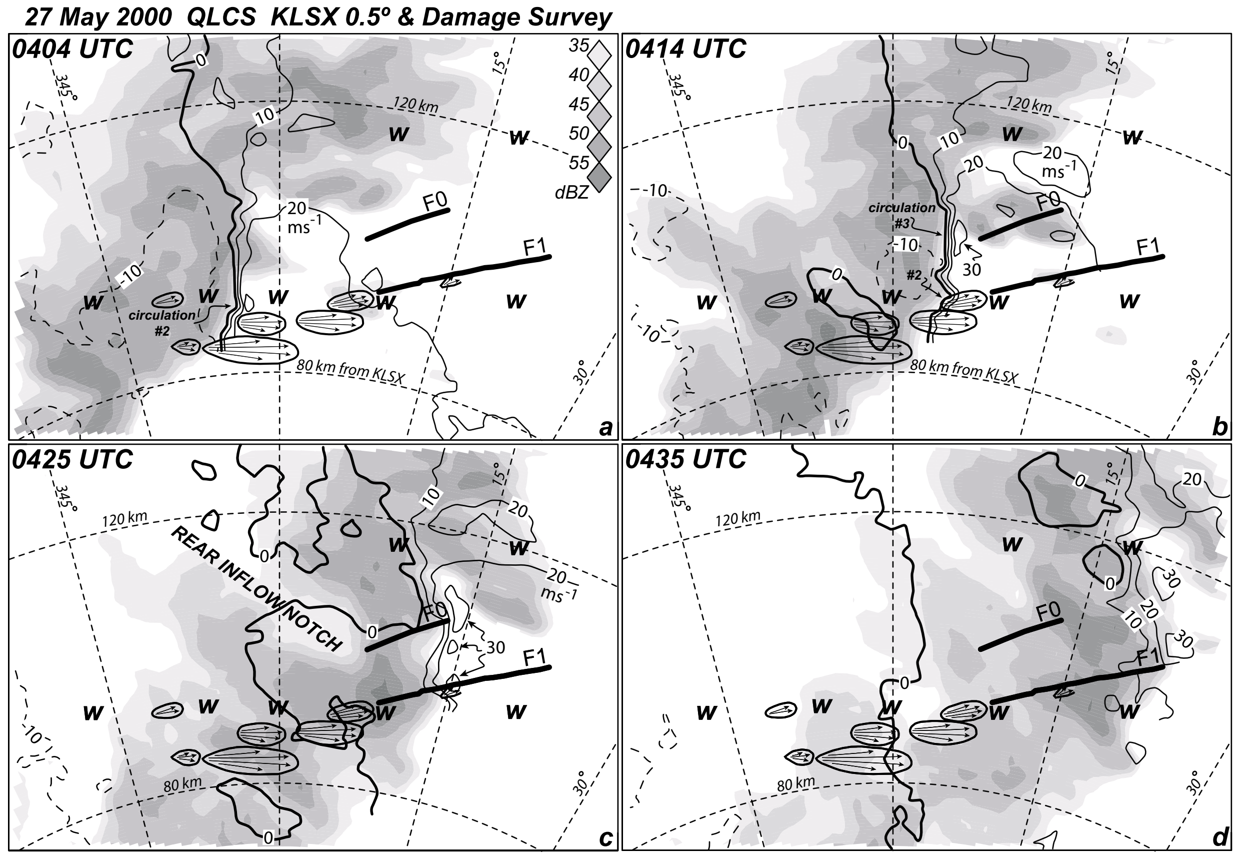

Figure 5. Radar reflectivity (gray) and radial Doppler velocities (solid and long dashed lines) at 0404, 0414, 0425 and 0435 UTC are shown. Areas of wind and tornado damage produced from the damage survey are also plotted. Short dashed lines are azimuth and range from the KLSX WSR-88D.

form at or just north of the apex of a well-defined bow echo. Damage survey results confirmed that this vortex produced F1 tornadic damage. However, the data also suggest that the vortex may have played a role in helping to produce straight-line wind damage prior to the time it became tornadic. Finally, circulation #1 produced F0 damage and formed just south of the merger point between the convective line and another cell ahead of it, very similar to vortex #1.

The observations discussed herein have illustrated the complicated relationship between the QLCS, vortices formed within it and the type of damage produced at the surface. In particular, the observations suggest that it may be possible for the intense low-level vortices to act together or independent of the rear-inflow jet to produce damaging straight-line winds. It has long been accepted that the rear inflow jet is responsible for the majority of the straight line wind damage produced by these systems. However, the data presented herein and other recent results (e.g., Schmocker et al. (2000) suggest that low-level vortices may play an important role in generating strong straight line wind damage at the surface. Future resolution of this question will require analyses of high-resolution radar and damage survey information and awaits further study.

Acknowledgements: The research results presented herein were supported by the National Science Foundation under Grant ATM-0100016

References